Section 4

4. Network Model Description

This section describes the network model representation of the network that supports the primary application used for TFM, ETMS. Specifically, it reveals details within the current network supporting ETMS traffic and explains the assumptions used to develop the both the infrastructure and the traffic for the network model.

4.1 SLAD Modeling Approach

The modeling approach comprises three steps as shown in Figure 4-1: Develop Baseline Model, Develop Analysis Scenarios, and Conduct System Loads Analysis. For Step 1, the traffic characteristics of each data flow are accurately represented and the model architecture is built. This step will be explored further in this section. In Step 2, analysis scenarios are developed to validate the baseline model and to explore the effects of future changes on system performance. These analysis scenarios are inputs to Step 3, Conduct System Loads Analysis. In this step, the model is executed and performance results are obtained to analyze network loading, throughput, and shortfalls. Steps 2 and 3 will be further detailed in Section 5 of this report.

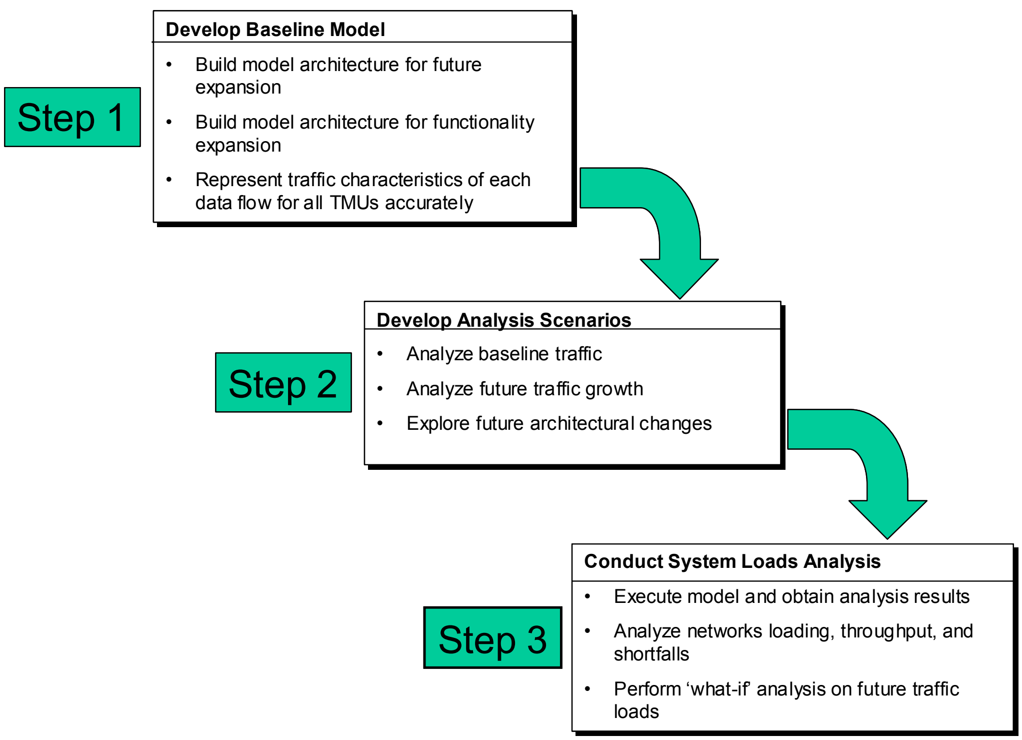

Figure 4-1: Modeling Approach

4.2 Develop Baseline Model

The purpose of the baseline model is as follows:

- Analyze the effect of each ETMS data flow on overall system performance
- Examine the performance of the network under average conditions
- Measure and quantify the effects of traffic changes by comparing the baseline results to the results of the analysis scenarios.

This section describes the methodology that was performed to develop the baseline model. It details the model's architecture and it provides an overview of the traffic that was used in the model for the baseline run.

4.2.1 Network Modeling Tool

To model the current FAA network supporting ETMS traffic, OPNET, a commercial-off-the-shelf discrete event simulation tool is used. OPNET is capable of modeling large communications networks and permits the simulation of both circuit-switched and packet-switched networks. In addition, because it is a programmable tool, OPNET allows for the modeling of non-standard telecommunications equipment. The various aspects of switch characteristics that can be customized are: capacity, switch behavior, protocols, routing techniques, server, workstations, and storage devices. As a result, it allows the user to create a model that mirrors the actual system as accurately as possible.

4.2.2 Network Model Architecture

The baseline model was developed using a three-phased approach. In the first phase, a single-link model consisting of VNTSC and an ARTCC was first built for data input verification as well as for validation of the ETMS data flow analysis. The calculated ETMS traffic was input into the model and the model was run to simulate five consecutive days. Simulation results for the single-link model accurately matched the actual traffic pattern and magnitude that was obtained from VNTSC network management statistics provided in the *ETMS WAN Loading Summary Data Report.*

The model's architecture was developed with consideration for scale expansion (e.g., representation of BWM nodes and FIRMNet routers). Thus, in the second phase, the model was expanded to 28 BWM nodes. The purpose of this phase was to capture the FIRMNet backbone topology as well as the ETMS traffic riding over it. It also provided a basis for modeling BWM node transmission and queuing delays. Thus, this expansion allowed the WAN response times for various TMUs to be estimated more accurately. Simulation results from the 28-node model also accurately matched the traffic pattern and statistics from VNTSC.

For the third phase, the 28 BWM node model was fully expanded to the current baseline model, which consists of 85 ETMS-enabled sites and 28 BWM nodes. Figure 4-2 shows the baseline network model with 28 BWM nodes.

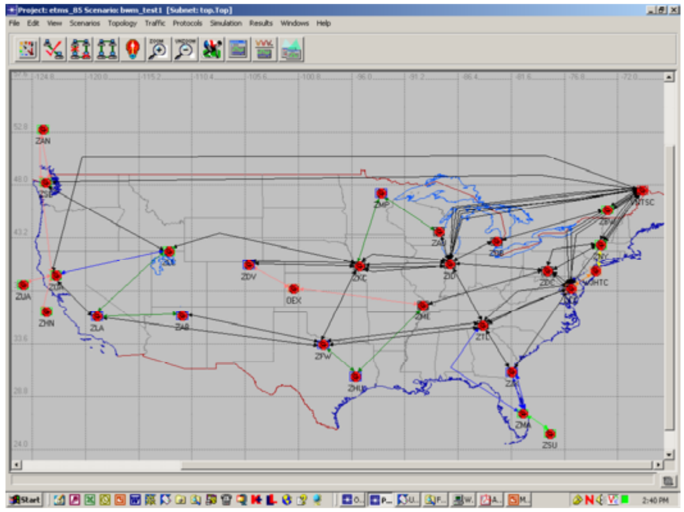

Figure 4-2: Network Model of 28 BWM nodes

Each of the 85 sites relies on one of the 28 BWM nodes for access to FIRMNet. Based on information from VNTSC, each one of the 85 sites is connected to a single BWM node in the model. Appendix A lists the ETMS-enabled sites included in the model and the BWM node to which they are homed. For example, in the Indianapolis region, there are three ETMS-enabled sites: the Indianapolis ARTCC, the Indianapolis TRACON, and the Cincinnati TRACON. All of these sites rely on a single BWM node in Indianapolis for access to the BWM network. This configuration is shown in Figure 4-3.

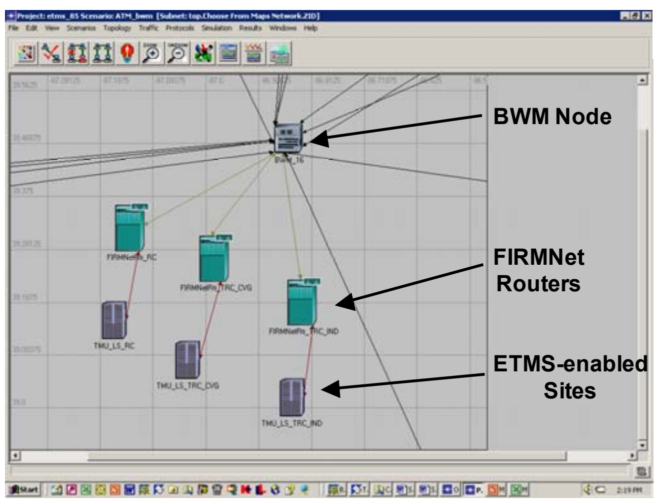

Figure 4-3: Indianapolis Region Network Configuration

Each ETMS site contains two components: a FIRMNet router and a local ETMS server. A Cisco 7513 router module is used to represent a FIRMNet router at each site. The router in conjunction with a BWM node provides access and transport through FIRMNet. In addition, there are local file servers at each site. File servers in this model represent end users and act as traffic generators. With the exception of VNTSC, which has two local file servers, each site has one file server.

As mentioned earlier, multiple sites may rely on a single BWM node to access the BWM network. In the actual BWM network, Promina 800 series switches are BWM nodes that provide the core switching capabilities of the network. Although Promina employs a proprietary communication protocol suite, vendor information reveals that the Promina 800 series are asynchronous transfer mode (ATM)-based network switching equipment; thus, the BWM nodes in the model are represented by generic ATM nodes.

Another aspect of the network represented in the model is the routing of the ETMS traffic. Network routing is based on a "FIRMNet Link Utilization Map" provided by the FAA and logical routing information provided by the WJHTC.

Figure 4-4 shows the 28 BWM nodes and the routing configuration between each site and VNTSC.

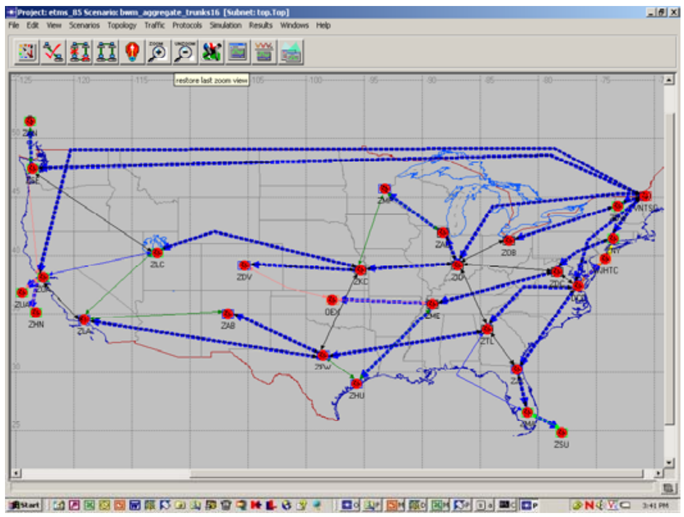

Figure 4-4: Routing Configuration of FIRMNet

4.2.3 Network Model Traffic

To accurately develop a network model to support future system decisions, a realistic traffic baseline profile is necessary. Section 3 describes the data flow analysis that was conducted to determine the amount of ETMS traffic generated and sent to each site. This information was then used in the model to characterize and represent the traffic traveling over FIRMNet. The following table summarizes the ETMS data flow parameters used in the model in terms of size, inter-arrival time, and the direction of flow.

Table 4-1: ETMS Data Flows

Data Flow	Size (Bytes)	Inter-arrival time (seconds)	Origination	Destination
Flight Data Distribution	7.7K	Exponential (the mean varies based on hour of the day)	VNTSC	TMUs
Weather Data	Nowrad2 134K	Constant (300)	VNTSC	TMUs

Data Flow	Size (Bytes)	Inter-arrival time (seconds)	Origination	Destination
	Nowrad2 Can 44K	Constant (900)		
	Nowrad2 SJ 7K	Constant (900)		
	Nowrad6 33K	Constant (300)		
	Nowrad6 Can 22K	Constant (900)		
	Nowrad6 SJ 4K	Constant (900)		
	Lightning 1K	Constant (300)		
	Echo Tops 2K	Constant (600)		
	Jet Streams 49K	Constant (10800)		
	Radar Tops 60K	Constant (300)		
	CCFP 1K	Constant (7200)		
Monitor Alert Data	173K	Constant (60)	VNTSC	TMUs
ADL Distribution	50K	Constant (300)	VNTSC	TMUs
GDP Data	139K	Exponential (19)	ATC SCC	VNTSC
FEA/FCA Data	Normal (6.5K – 13K)	Constant (60)	VNTSC	Initiating TMU
Reroute Data	Normal (18K – 30K)	Exponential (600)	VNTSC	Initiating TMU
TMS/TMC Retrieval	Normal (1K – 3K)	Exponential (240)	VNTSC	TMUs
TMS/TMC Update	Normal (1K – 3K)	Exponential (720)	TMUs	VNTSC
NAS Flight Data[3]	20 – 105	Exponential (the mean varies based on message source)	TMUs	VNTSC
RVR Data	1060	Constant (2)	TRACON	VNTSC

As the table reveals, most of ETMS traffic flows from VNTSC to the other sites. Specifically, Flight Data Distribution, Weather, Monitor Alert, and ADL traffic represent more than 90 percent of the overall ETMS data traffic.

[3] The specified range for NAS Flight Data represents the message sizes sent from each TMU.

As mentioned earlier, the results of the data flow analysis was used to populate Table 4-1, which are the traffic parameters into the model. The baseline model only uses the mean message size to represent the traffic. Thus, the baseline model represents a typical day under normal air traffic operations.

As discussed in Section 3, information was not available for several of the flows namely, FEA/FCA Data, Reroute Data, and TMS/TMC Update and Retrieval Data. For the message size and inter-arrival time of Reroute Data and TMS/TMC Update and Retrieval Data flows, a normal distribution and exponential distribution, respectively, was assumed. While the message size for the FEA/FCA Data flow is also normally distributed, its inter-arrival time is fixed. Finally, for RVR Data, the message size and inter-arrival time are fixed.

Similarly, for the data flows with variable inter-arrival times, such as GDP Data, the frequency was represented by an exponential distribution. With respect to Flight Data Distribution and NAS Flight Data, due to the nature of these data flows, the mean of the exponential distribution used for the inter-arrival time varies as well. Specifically, the frequency of the Flight Data Distribution varies throughout the day based on different levels of air traffic activity. Additionally, for NAS Flight Data, each TMU sends NAS Flight Data messages at different rates. Thus, to account for these factors, these two data flows were represented by exponential distributions with various mean inter-arrival times.

4.3 Baseline Run Model Results

Due to the complexity of the model (e.g., 85 sites, 12 data flows), it takes 24 hours of runtime to simulate 1 hour of baseline traffic. For the baseline run, although it would be ideal to simulate an entire day, the simulation was limited to the eight consecutive busiest hours (1600Z–0000Z) of a day due to time constraints. The following figures show the results of this baseline run. Figure 4-5 shows the ETMS traffic profile entering and leaving TMUs. For visualization purposes, Figure 4-5 shows representative TMUs, based on the ranking noted in Section 3.3.6, and the amount of downlink and uplink traffic terminating and originating at these locations.

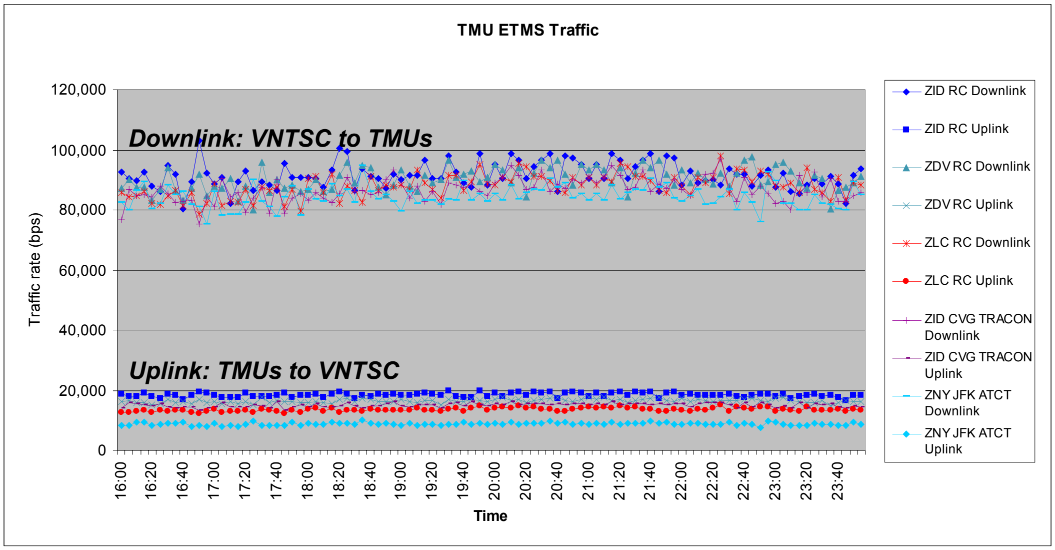

Figure 4-5: Baseline Run - TMU Traffic Profile

As shown in Figure 4-5, ETMS traffic entering the TMUs is much greater than ETMS traffic leaving the TMUs during the busiest hours of an average day. Specifically, the downlink traffic ranges between 80 Kilobits per second (Kbps) and 100 Kbps, whereas the uplink traffic only ranges between 10 Kbps and 20 Kbps. Figure 4-6 reveals the ETMS traffic profile entering and leaving the VNTSC for the same 8 consecutive hours.

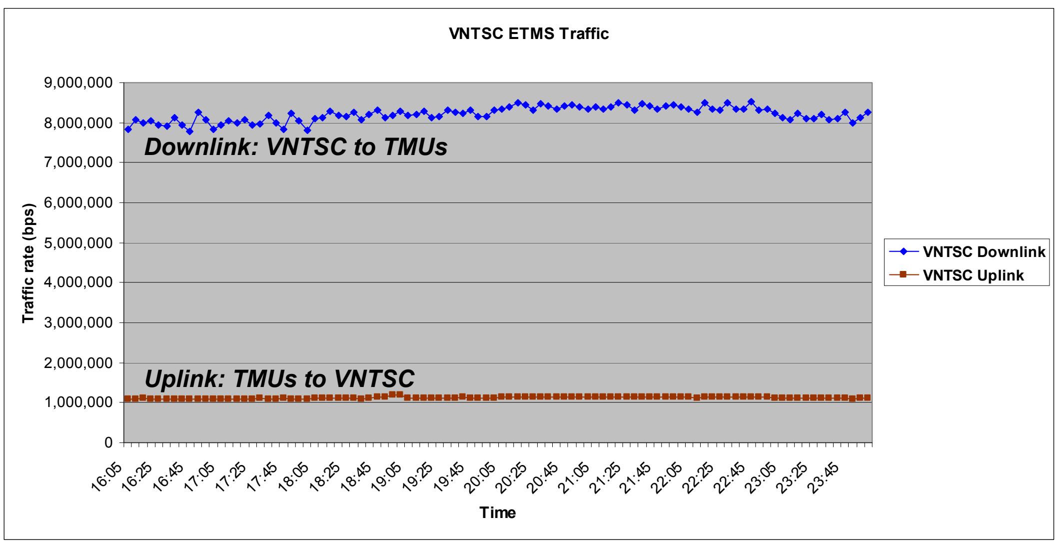

Figure 4-6: Baseline Run - VNTSC Traffic Profile

Similarly, Figure 4-6 shows that the amount of traffic leaving VNTSC is much greater than the amount of traffic entering VNTSC. Specifically, the downlink traffic during the busy hours of a day is approximately 8,000 Kbps, whereas the uplink traffic averages 1,000 Kbps. Thus, the results of the baseline run validate the assumption that traffic leaving VNTSC and entering the TMUs is much heavier than the traffic entering VNTSC and leaving the TMUs.

Table 4-2 shows the ETMS percentage of backbone utilization for all backbone links. Overall, the average backbone utilization on a typical day with normal air traffic operations is 19 percent. Results show that the links with the highest ETMS utilization percentage are those between ZNY and ZDC, and between VNTSC and ZNY. Each of these links are 48 percent and 47 percent utilized, respectively. As also shown in the table, some links have zero ETMS utilization. This implies that these links are not typically used for the routing of ETMS traffic but may be used by other applications or for traffic re-routing during contingencies.

Table 4-2: Baseline Run - Backbone Utilization

Origination-Destination Pair		Average Utilization	Origination-Destination Pair		Average Utilization
ZDC	ZNY	48%	ZKC	ZLC	18%
VNTSC	ZNY	47%	ZID	ZKC	16%
ZDC	ZME	38%	ZDV	ZKC	13%
ZHN	ZOA	38%	ZAB	ZFW	13%
ZHU	ZME	38%	OEX	ZME	12%
ZAU	ZMP	38%	DCC	ZDC	0%
ZAN	ZSE	37%	OEX	ZDV	0%
DCC	ZJX	37%	WJHTC	ZNY	0%
ZOA	ZUA	37%	ZAB	ZLA	0%
ZAU	ZID	37%	ZDC	ZID	0%
VNTSC	ZSE	37%	ZFW	ZHU	0%
VNTSC	ZOA	37%	ZFW	ZKC	0%
DCC	WJHTC	36%	ZID	ZOB	0%
DCC	ZTL	31%	ZID	ZTL	0%
ZFW	ZTL	31%	ZJX	ZTL	0%
ZFW	ZLA	30%	ZKC	ZMP	0%
DCC	VNTSC	28%	ZLA	ZLC	0%
ZMA	ZSU	26%	ZLA	ZOA	0%
VNTSC	ZID	25%	ZLC	ZOA	0%
ZJX	ZMA	25%	ZLC	ZSE	0%
ZBW	ZOB	25%	ZMA	ZTL	0%
VNTSC	ZBW	21%	ZOA	ZSE	0%

Other conclusions and observations resulting from the simulation of the ETMS network are summarized as follows:

- The downlink traffic varies greatly over a day and obeys certain patterns or traffic profiles
- The four primary data flows (i.e., Flight Data Distribution, Weather, Monitor Alert, and ADL) constitute more than 90 percent of the overall downlink traffic represented in the model
- Flight Data Distribution dominates the downlink data traffic and dictates the traffic profile
- Monitor Alert and Weather Data are the major sources of traffic bursts
- System capacity is provisioned to accommodate the peak hour traffic load.

The baseline network model simulates with reasonable accuracy the ETMS traffic and network conditions experienced on a typical day.